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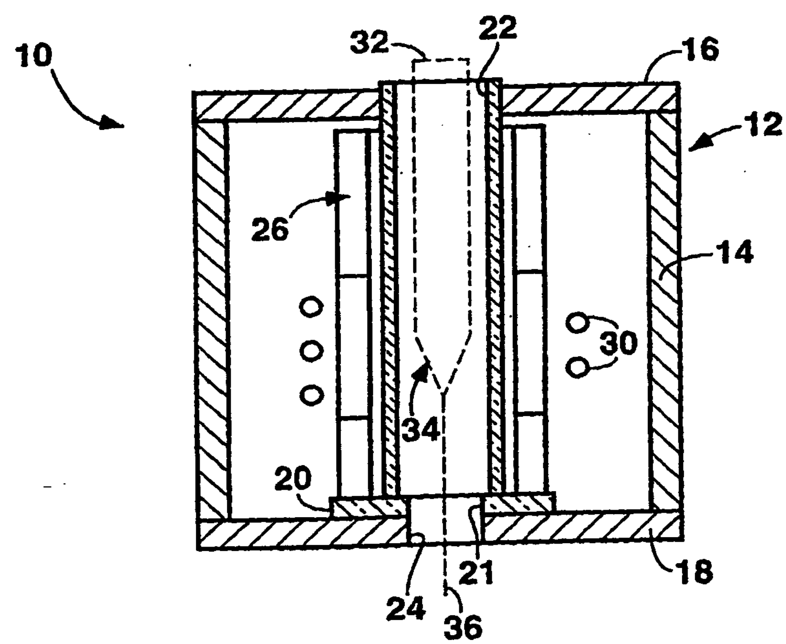
(54) Title: APPARATUS AND METHOD FOR DRAWING WAVEGUIDE FIBERS



(57) Abstract

A furnace (12) has a muffle tube (22) that is coated with silicon carbide. It is tubular. They make a fiber (36) with it.

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APPARATUS AND METHOD FOR DRAWING WAVEGUIDE FIBERS

FIELD OF THE INVENTION

The present invention relates to a method and apparatus for drawing waveguide fibers. More particularly, the present invention relates to a furnace that significantly reduces point defect losses in fibers generated during the draw process.

BACKGROUND OF THE INVENTION

Relatively high temperature heat sources are required for drawing high strength, low loss fibers from a high silica-content fiber preform or blank. The two predominant heat sources that have been utilized for drawing such fibers are zirconia and graphite furnaces. Fiber draw furnaces generally operate at temperatures greater than about 1900°C, typically as high as about 2050°C.

A zirconia induction furnace conventionally includes a housing in which there is a centrally disposed tubular, yttria-stabilized zirconia susceptor surrounded by a cylindrical quartz beaker containing granular zirconia insulating material. An induction coil surrounding the insulating material provides an alternating

electromagnetic field when energized. The field couples to the susceptor and raises the temperature of the susceptor to form a hot zone. An end portion of glass optical fiber preform is lowered into the hot zone to melt the end portion and a fiber is drawn from this melted end portion.

One disadvantage associated with zirconia induction furnaces is that extended use and thermomechanical stresses cause cracks in the muffle and susceptor. This cracking causes zirconia particles to migrate from the inner surface of the furnace onto the preform and/or fiber being drawn from the preform resulting in substantially weakened fiber and unacceptable product losses.

Graphite induction furnaces typically have a graphite muffle that is less susceptible to cracking, but graphite furnaces suffer from the disadvantage that the graphite muffle oxidizes at high drawing temperatures. It has been suggested that drawing a waveguide fiber in a graphite furnace must be performed in an inert protective atmosphere to prevent oxidation of the furnace muffle. Oxidation occurs when gasses from ambient atmosphere react with the solid carbon muffle at high temperatures according to the following reactions:

(1) $C + O_2 \rightarrow CO_2$

(2) $C + CO_2 \rightarrow 2CO$.

A typical onset temperature for reaction (1) for a graphite grade used in a draw furnace is about 700°C. Reaction (2) becomes significant above 900°C. These reactions of the furnace muffle with oxygen and carbon dioxide cause the furnace muffle to be consumed, especially at elevated fiber drawing temperatures.

The graphite muffle material is a composite of graphite grains bonded together by a carbon binder matrix. It is believed that the binder material is more

susceptible to oxidation than the graphite grains. Therefore, when the composite of the two materials is exposed to oxygen at temperatures above the oxidation onset temperatures, the matrix binder material preferentially oxidizes. The graphite grains, having no binder left to hold them place, are then free to fall away from the composite structure. It is believed that this mechanism causes graphite particulate to migrate from the muffle wall to the fiber preform and/or fiber during drawing.

Graphite particulate that becomes incorporated into the fiber during drawing causes unacceptable product losses due to point defects. Point defects manifest themselves as sharp attenuation increases in the signal transmitted through the fiber. Point defect product losses due to graphite particulate from a draw furnace losses can be greater than about 5%, which is an unacceptably high loss. Graphite particulate that has adhered to the fiber during the draw process also contributes to fiber breaks.

As mentioned above, it has been suggested that oxidation of the graphite furnace muffle may be overcome by drawing in an inert, protective gas atmosphere. The outer surface of a graphite muffle may be insulated by enclosing the muffle in a housing and flowing inert gas between the housing and the outer wall of the muffle. However, it is difficult to eliminate all oxygen from the furnace muffle, especially the inner surface of the muffle which is exposed to oxygen from ambient air that may leak into the furnace during loading and unloading waveguide fiber preforms. In addition, oxygen is believed to be present in the furnace due to the difficulty in eliminating oxidants from the furnace. For example, the upper region of the muffle is susceptible to oxidation

from the oxygen-containing porous soot section of an optical fiber blank that dwells in the furnace muffle during loading of the blank in the furnace. It is believed that oxygen present in the porous region of the blank oxidizes the muffle, producing graphite particulate.

In view of the above considerations, it would be desirable to provide a graphite fiber draw furnace muffle that does not generate graphite particulate, and thus significantly reduces point defect losses in the fiber.

SUMMARY OF INVENTION

Accordingly, the present invention generally provides an apparatus for heating a glass waveguide fiber preform to a temperature sufficient to draw a fiber therefrom comprising a generally tubular graphite muffle including an inner surface having a coating of high purity silicon carbide on the inner surface of the muffle. The coating preferably has a thickness of at least about 2 mils and contains less than about 900 parts per billion impurities.

In another aspect, the invention provides a method for producing a waveguide fiber in a draw furnace including a generally tubular graphite muffle having an inner surface. The method includes the steps of providing a high purity silicon carbon coating on the inner surface of the graphite muffle. The method further includes disposing a waveguide fiber preform in the furnace muffle, heating the furnace to a temperature sufficient to draw fiber from the preform, and drawing fiber from the blank.

Several important advantages will be appreciated from the foregoing summary. The principal advantage of the present invention is significantly reducing point defect losses in waveguide fibers drawn in a furnace having a graphite muffle. Additional features and advantages of

the invention will be set forth in the description which follows. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed. Various elements of the accompanying drawing are not intended to be drawn to scale, but instead are sometimes purposely distorted for the purposes of illustrating the invention.

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 is a schematic illustration of an exemplary embodiment of optical fiber draw furnace of the present invention.

DETAILED DESCRIPTION

Reference will now be made in detail to the present preferred embodiment of the invention, an example of which is illustrated in the accompanying drawing.

The present invention includes an apparatus for heating a waveguide fiber to a temperature sufficient to draw a fiber therefrom. An exemplary embodiment of the present invention is shown in Fig. 1 and is designated generally by reference numeral 10.

As embodied herein and referring to Fig. 1, furnace 10 is comprised of a generally cylindrical housing 12 having a side wall 14, a top portion 16, and a bottom portion 18. Top portion 16 has a central opening 22 therein which is vertically aligned with an opening 24 in bottom portion 18. Insulating material 26 is axially disposed in housing 12, which may be formed from a plurality of segments. A generally tubular, graphite

muffle 28 is centrally located within the insulating material 26. The muffle 28 and insulating material may be separated from the bottom portion 18 by a spacer ring 20 having an aperture 21 through which fiber is drawn to insulate the muffle from the bottom portion. The spacer ring 20 may be made from silica. An induction coil 30, which is connected to a power source (not shown), surrounds the insulating material 26 to provide a heating source for the furnace 10.

Housing 12, which is water cooled, may be fabricated of stainless steel or the like. Preferably, housing 12 axially runs the full length of the muffle 26 to fully enclose the muffle. An inert gas such as argon is flowed into the housing 12 to prevent oxidation of the outer surface of the muffle 26.

A waveguide fiber preform 32 (shown in phantom) is axially inserted into muffle 26 until a first end 34 thereof is position at the "hot zone" located within the induction coil 30. After hot zone has reached a temperature sufficient to draw fiber from the preform, which is preferably above 1900°C, an optical fiber 36 is drawn from the end portion 34 of the preform 32. In an important aspect of the invention, the inner surface of the muffle 28 adjacent the preform 32 has a coating of high purity silicon carbide thereon to prevent deterioration of the graphite muffle. The graphite muffle 28 preferably comprises at least two and, more preferably, three axial segments because it is difficult to coat sections of the muffle longer than about 40 inches.

The thickness of the silicon carbide coating is preferably at least about 2 mils and less than about 100 mils. Coating thinner than about 2 mils does not adequately prevent graphite particulate from contaminating fiber drawn from the furnace, and coating thicker than

about 100 mils is susceptible to microcracking and thermal shock. The thermal expansion of the SiC coating must be closely matched to the carbon binder matrix material which holds the graphite grains of the muffle together to prevent delamination of the coating due to thermal expansion mismatch.

The silicon carbide coating in the inner surface of the muffle is preferably formed by a chemical vapor deposition process using a silicon containing gas. Such a coating may be formed by reacting a silicon containing gas such as a silane with hydrogen to form SiC, wherein the silicon and carbon are present in a ratio of about one to one. The SiC is coated on the inner surface of the substrate which has been heated above 1000°C. High purity coatings are preferred on the inner surface of the draw furnace muffle to prevent contamination of fibers drawn in the furnace of the present invention. Preferably the impurity level in the silicon carbide coating is less than about 900 parts per billion, and more preferably less than about 200 parts per billion.

Another aspect of the present invention is directed to a method for producing a waveguide fiber in a draw furnace including a graphite, generally tubular muffle having an inner surface. The method comprises the steps of providing a high purity silicon carbide coating on the inner surface of the graphite muffle, disposing a waveguide fiber preform in the muffle, heating the furnace to a temperature sufficient to form draw fiber from the preform, and drawing fiber from the preform.

The furnace is preferably heated to a temperature of at least about 1900°C, more preferably to at least about 2000°C, to enable the tip of the waveguide preform to soften and allow fiber to be drawn therefrom. The high purity silicon carbide is preferably about 99.999% pure,

and more preferably contains less than about 900 parts per billion of impurities. The low impurity level is an important aspect of the present invention because higher impurity levels may cause optical or mechanical defects in the fiber produced in the furnace.

Waveguide fibers produced by utilizing the furnace and method of the present invention exhibit significantly reduced point defect losses. Fibers drawn in a conventional graphite muffle draw furnace exhibited product losses from attenuation due to point defects of approximately 5%. Fibers produced in a furnace of the present invention including a generally tubular, graphite muffle having an inner surface thereof coated with a silicon carbide layer about 5-8 microns thick exhibited product losses from attenuation due to point defects of approximately 0.8%.

It will be apparent to those skilled in the art that various modifications and variations can be made in the method and apparatus of the present invention without departing from the spirit or scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

CLAIMS

What is claimed is:

1. A furnace for heating a glass waveguide fiber preform to a temperature sufficient to draw a fiber therefrom comprising a graphite, generally tubular muffle including an inner surface having a coating of high purity silicon carbide on the inner surface of the muffle.

2. The furnace of claim 1, wherein the muffle further comprises at least two generally tubular sections.

3. The furnace of claim 2, wherein the muffle comprises three generally tubular sections.

4. The furnace of claim 1, wherein the coating has a thickness of at least about 2 mils.

5. The furnace of claim 1, wherein the silicon carbide contains less than about 900 parts per billion of impurities.

6. A method for producing a waveguide fiber in a draw furnace including a graphite, generally tubular muffle having an inner surface comprising the steps of:

providing a high purity silicon carbide coating on the inner surface of the graphite muffle;

disposing waveguide fiber preform in the muffle;

heating the furnace to a temperature sufficient to draw fiber from the preform; and

drawing fiber from the preform.

7. The method of claim 6, wherein the temperature of furnace is at least about 1900°C.

8. The method of claim 6, wherein the temperature of the furnace is at least about 2000°C.

9. The method of claim 6, wherein the silicon carbide contains less than about 900 parts per billion of impurities.

10. The method of claim 6, wherein the waveguide fiber drawn from the furnace has a point defect loss less than about 4%.

11. The method of claim 1, wherein the waveguide fiber drawn from the furnace has a point defect loss less than about 1%.

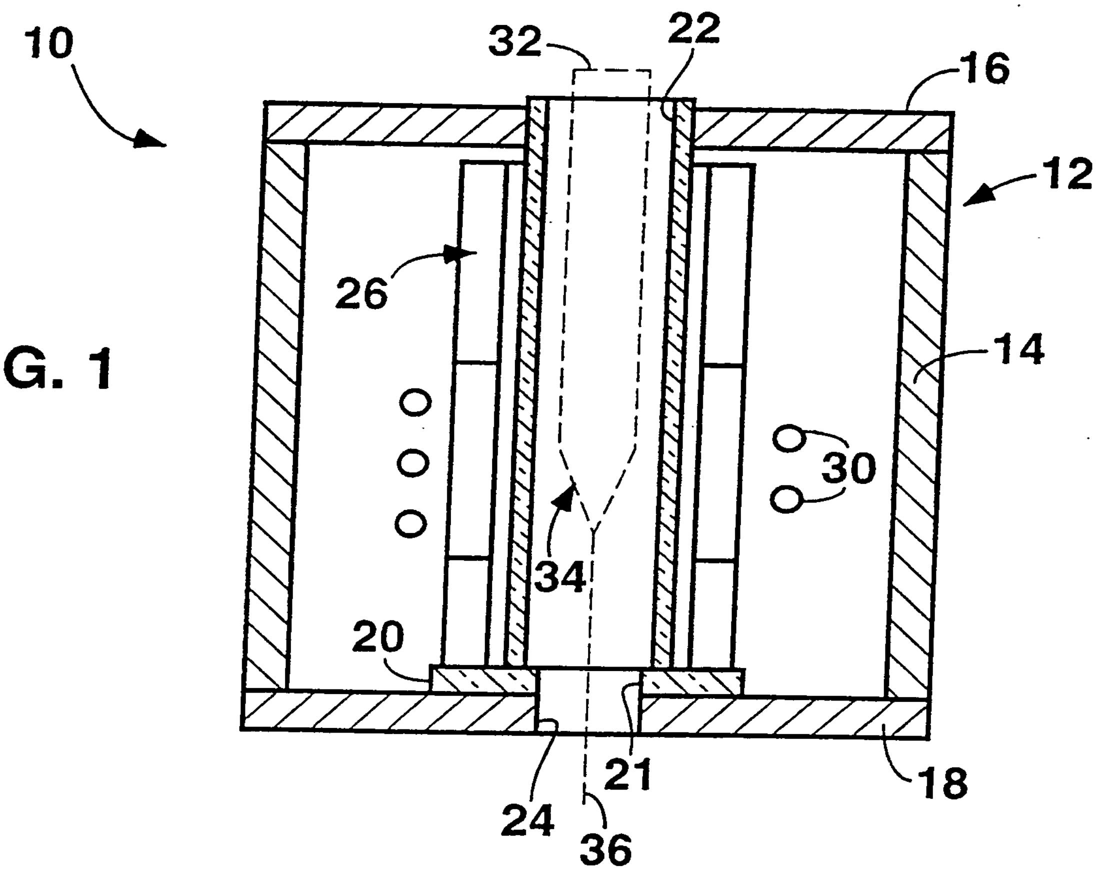

FIG. 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/21872

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :C03B 37/05, 37/03
US CL :65/374.13, 374,15, 435, 537
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 65/374.13, 374,15, 435, 537

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,306,322 A (ISHIKAWA et al) 26 April 1994, the abstract.	1,4-11
Y	US 5,032,079 A (TSUCHIYA et al) 16 July 1991, see entire document.	1-3

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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